

Er-doped GaN: Bonding, Structure, and 1.54- μm Emission

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Despite the need for smaller systems with higher gain in the 1.54- μm Er-luminescence region, almost all studies of Er-doped GaN have focused instead (for other applications) on the observed intense, visible (green) Er luminescence. The goals of this work are to understand why GaN is such a good host for Er, to assess the GaN:Er luminescence intensity at 1.54 μm , and to explore the feasibility of using GaN:Er in future optoelectronics systems.

X-ray absorption measurements, thermodynamic bond energies, and simple chemical concepts were combined to give a clear, consistent picture: Er readily replaces Ga in GaN, resulting in unusually short Er–N bonds due to the low fourfold coordination and ionic character of substitutional Er (first-principles calculations of the anomalous Er–N distances in GaN:Er are within 0.01 Å of experiment). The significant bond strength between Er and N explains the observed insensitivity of Er to O gettering, and accounts for the large crystal-field splitting of Er 4*f* states in optically favorable, T_d -symmetric sites (no inversion symmetry makes the otherwise forbidden 4*f* intrashell transitions allowed). The observation of negligible lattice displacements for Ga or N atoms ≥ 5 Å from Er (due to the comparable size and charge of Er vs Ga) implies that average Er-Er separations of ~ 10 Å, or effective Er concentrations as high as $\sim 10^{21}$ atoms/cm³ (~ 1 at. %), should be possible before effects of strain and/or site inhomogeneities become important. This expectation was confirmed in measurements of Er luminescence intensities from a series of MBE-grown samples, showing that the 1.54- μm luminescence directly scales with Er concentrations up to ≥ 1 at. %. Such a high concentration is about ten times greater than that in the best performing Er-doped aluminosilicate waveguide amplifiers. Measurements of linear (small-signal) gain, which depend on sample and coupling geometries, await availability of suitably prepared GaN:Er samples.